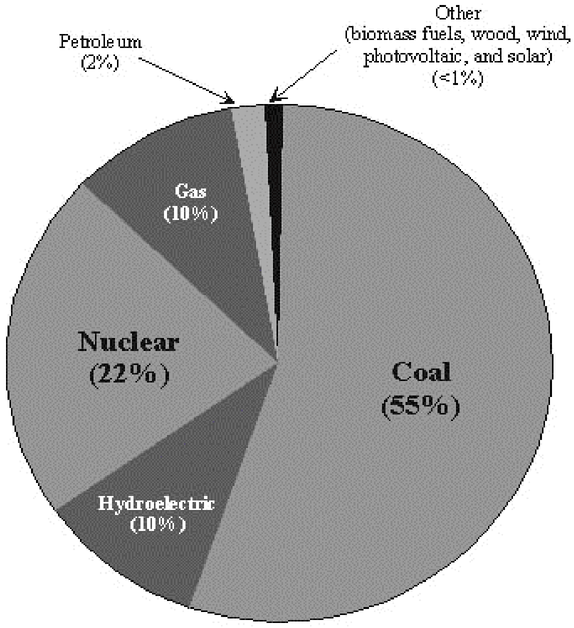
ENERGY PRODUCING SYSTEMS

NUCLEAR POWER

INTRODUCTION

Nuclear energy involves harnessing the power of the atom. Atoms are the fundamental building blocks of matter and are composed of protons, neutrons and electrons. The forces that hold the central part (nucleus) of the atom together are immense. Two processes are possible that can release this energy. *Fusion* involves combining the nuclei of two or more atoms. *Fission* and involves breaking the nucleus apart. In either case very large quantities of energy can be released.

All nuclear power plants currently operate using fission reactions (*splitting the atom*). Part of the energy released by fission reactions is in the form of thermal energy. It is this thermal energy that is used to heat water to steam and drive turbine systems designed to produce electricity. During this process the fission reactions also produce a form of energy called *radiation* along with solid radioactive waste products. Radiation is a very powerful form of energy that can cause cell damage and impair cell function of living organisms. Care must be taken in designing and operating nuclear power plants in order to appropriately contain the resulting radioactive by-products.



Electrical Production by Type

Source: Nuclear Regulatory Commission

More than 30 countries have developed nuclear power programs and there are more than 400 nuclear reactors worldwide. Of these facilities, one fourth are located in the United States. Currently nuclear power is second only to coal in the generation of electrical power in the United States and provides 22 percent of our electrical needs.

NUCLEAR POWER SYSTEMS

FISSION REACTORS

The only form of nuclear power generation in use today involves fission reactor plants. In addition to generating electrical power for general use, such power systems are used by the military to power submarines and other large navel vessels. Fission reactors basically involve splitting atoms apart under controlled conditions. Uranium (U-235) is the fuel used by most nuclear power systems. First, the uranium is processed (concentrated) from mineral deposits and then formed into fuel pellets. These fuel pellets are stacked in stainless steel tubes called fuel rods. When an atom of uranium splits it ejects a stream of neutrons. These neutrons collide with nearby uranium atoms causing more atoms to split and thus releasing even more neutrons. The whole process gains momentum in what is called a *chain reaction*. By controlling the number of fuel rods and their proximity to each other, the nuclear plant operators control the rate of these nuclear chain reactions. The fission reactions also release energy in the form of radioactivity and thermal energy (heat). Typically the entire assembly of fuel rods is submerged in a sealed tank of water and the resulting heat from the fission reactions used to generate steam. The steam is then used to drive turbines to generate electricity or operate large motors as in the case of a nuclear navel vessel. The overall approach is similar to that used by coal-fired or natural gas power plants, except the heat is provided by the nuclear reactions. The rate of the chain reactions must be carefully controlled and the radioactive by-products that result from the nuclear reactions must be carefully handled and properly disposed of.

FUSION REACTIONS

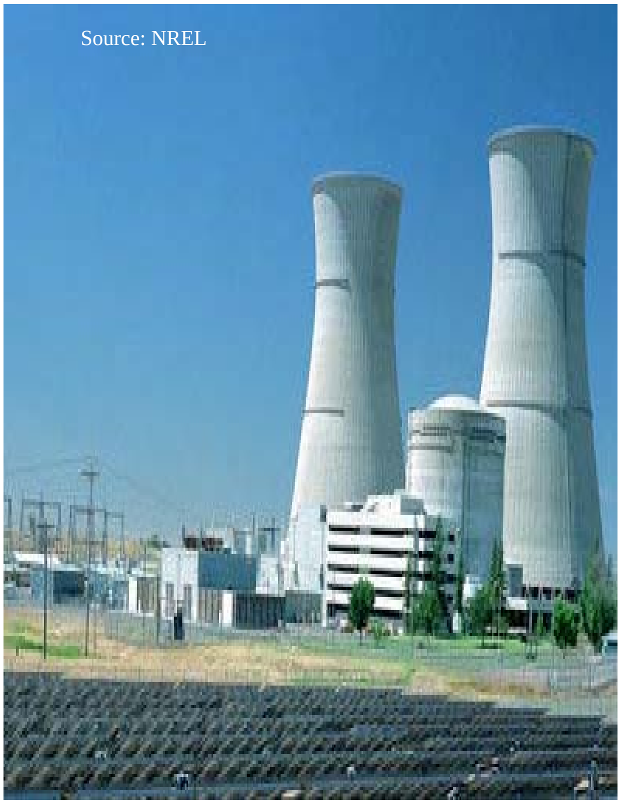
The heat of our sun is basically the result of a massive set of on-going nuclear fusion reactions. The process is so intense that you can step out side on a sunny day and feel the heat from these nuclear reactions even though the sun is more than 80 million miles away. The sun's gravitational forces and immense heat are so intense that the nuclei (center) of millions of hydrogen atoms are continuously being combined.

Currently scientific teams are working on ways to create fusion-type reactions for our own power needs. This would be an attractive source of power because many of the radioactive byproducts and disposal problems associated with *fission* reactions would be eliminated. Currently the amount of energy required to create even a small fusion reaction in the laboratory is far greater than the energy gained from the fusion event. If scientists can determine a practical way to induce fusion this may be a very attractive energy source indeed.

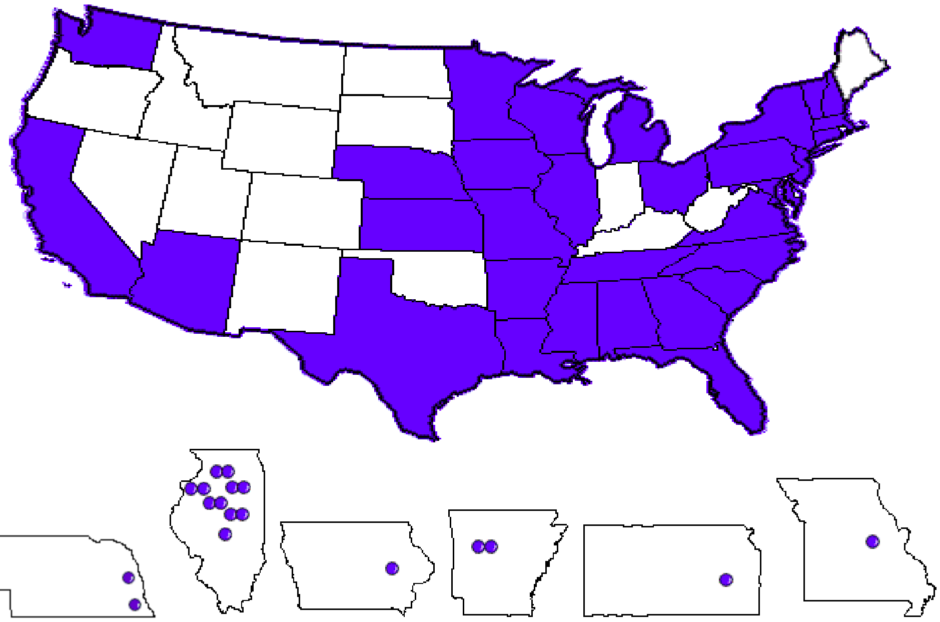
NUCLEAR POWER LOCATIONS

Nuclear power plants can be located in a number of areas. For safety reasons the site selected should be geologically stable. It is inappropriate to locate these facilities in high population zones such as highly urbanized areas. Often a lake or other body of water such as river is incorporated into the plant site selection. The source of water is required to cool and control the nuclear reactions and to generate steam. Most nuclear power utilities are engineered so that the nuclear reactions take place in a contained system designed to transfer the heat generated into an external water supply.

Nuclear power plants often have very large cooling towers used to cool and condense the steam after is has expanded through the systems of electrical turbines. The "smoke" that is released from the top of these cooling towers is actually water vapor and does not contain any radioactivity. A nuclear plant that is properly designed does not release radiation during normal operation. However, radioactive waste is generated each time the fuel rods are changed and short or long-term storage of such waste is a factor in site selection. In the United States all such waste is currently stored on-site at each facility.


Source: NREL

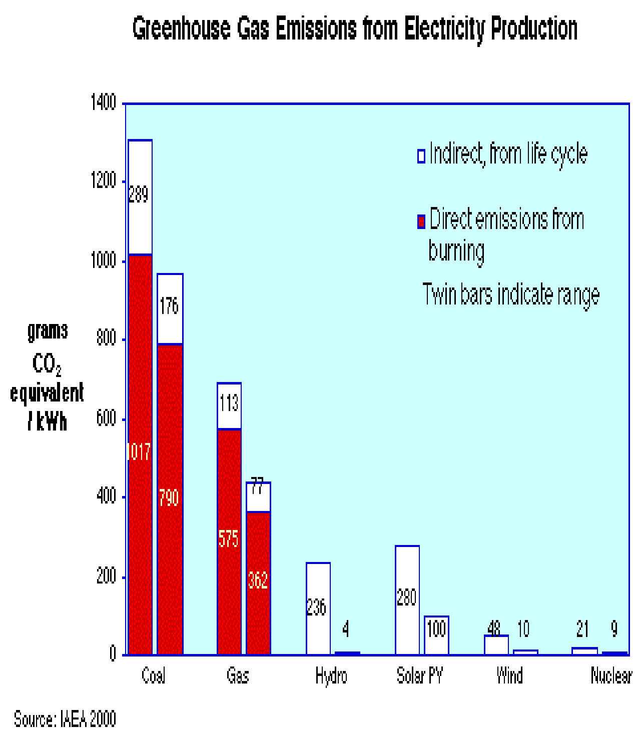
The following map indicates which states have nuclear power. Maps of Missouri and surrounding states are provided indicating the specific locations of the nuclear power plants (source: Nuclear Energy Institute)



Nebraska Illinois Iowa Arkansas Kansas Missouri

SPECIFIC CHARACTERISTICS OF NUCLEAR POWER

Nuclear energy cannot be classified as a renewable energy source. The raw material used to generate nuclear power (Uranium-235, and related radioisotopes) are mined from mineral deposits in the earth's crust. The supply of these radioisotopes will not last forever. It is projected that there should be enough radioisotopes to provide the raw materials for at least two hundred or more years of nuclear power. Nuclear power has the advantage of producing very low air emissions when compared to other forms of energy production (see table).



There are safety issues unique to nuclear power. Even when operated correctly a nuclear power plant still produces high-level radioactive waste every time the fuel rods are replaced, which depending on reactor design, will be every few years. High-level radioactive waste must be handled and stored carefully. Exposure to such radioactivity can cause serious damage to biological systems and even death. Radioactivity has also been linked to an increased risk of cancer and other diseases. Although nuclear waste will slowly lose its radioactivity via a process called radioactive decay, most waste being generated by nuclear power plants today can be expected to remain an active health risk for many thousands of years. As a result, storage and transportation of this waste is a major safety concern.

In 1979 an accident at the Three Mile Island nuclear plant near Middletown, Pennsylvania became the most serious in the history of U.S. commercial nuclear power to date. The accident involved a sequence of events related to equipment malfunctions, design problems and worker error. These problems led to significant damage of the reactor core and the release of a small amount of radioactivity off-site. Although high levels of radiation where released when the reactor core was insufficiently cooled, it was mostly limited to the containment building. No deaths or injuries to plant workers or members of the nearby community occurred as a result of the accident. The Three Mile Island plant was no longer operational following the accident and has been partially decommissioned.

Several factors contribute to the increased cost of nuclear power as compared to producing electricity from coal or natural gas:

- The expense involved in mining and processing the uranium.
- As much as one-third the cost of constructing and operating a reactor in the United States is associated with safety systems and structures.
- The radioactive waste that is generated by nuclear reactors must be handled and stored correctly.
- No permanent storage facility has been approved in the United States forcing nuclear plants to store radioactive waste on-site at significant expense.
- Most nuclear power plants are designed for an operational life span of 40-60 years and at the end of this time frame the plant must be fully refitted or decommissioned.
- A nuclear plant cannot just be shut down and simply closed. The plants core reactor needs to be dismantled and removed very carefully and handled as a radioactive waste. This process is very expensive and factors heavily into the price of energy from nuclear power.
- In the United States the price of electricity from nuclear power may even increase slightly because of the growing cost of disposal and decommissioning (dismantling the plant).

NOTE: Utilities are required to charge customers a fee to help cover the eventual costs associated with the above activities.

Another far more serious accident occurred in the Soviet Union (Russia) in 1986. The accident at the Russian nuclear plant located in Chernobyl, Ukraine caused the evacuation of 135,000 people and seriously contaminated an 18-square mile zone around the plant.

"The accident destroyed the reactor and released massive amounts of radioactivity into the environment" – U.S. Nuclear Regulatory Commission, Fact Sheet.

Chernobyl caused radioactive contamination as far away as Europe and was even detectable in the United States. Thirty-one people died within 10 days of the accident, mostly those fighting fires at the accident site. However, delayed health effects to others were likely extensive. Details are still not available and estimates vary. The Ukrainian Radiological Studies Center has reported over 2,500 deaths as a result of the accident.

Following the Chernobyl accident, a significant amount of criticism arose concerning the Russian plant design. Nuclear power plants operated in the United States have far more robust containment structures and additional safety systems. The value of such features was demonstrated during the Three Mile Island event, where radioactive exposure following the accident was minimal.

THE FUTURE OF NUCLEAR POWER IN MISSOURI

Missouri has a nuclear power plant located in Callaway County, 80 miles west of St. Louis. The reactor is operated by Ameren UE and was built in 1984. The plant is licensed until 2024 and provides approximately 11% of the electricity consumed in Missouri (*Ameren UE).*

Nuclear energy as a whole is on the decline as a result of safety concerns, waste disposal issues and economics. The United States currently generates more than 20 percent of its electricity from nuclear energy. This is projected to drop to less than 12 percent by the year 2020 (*Department of Energy*).

Nearly one-third of the nuclear plants in the U.S. are now more than 30 years old. No new plants have been constructed since 1996. A similar pattern is underway in Europe and worldwide. Areas where growth in nuclear power is still projected concern mostly parts of Asia and the Middle East (Korea, China, Japan and Iran).